

Mechanical Engineering Safety Note – PEPC Spreader Bar Assembly

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MECHANICAL ENGINEERING SAFETY NOTE

MESN01-092-OA

26 August 2001

PEPC Spreader Bar Assembly

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Section A: Equipment Description

The PEPC Spreader Bar Assembly consists of a spreader bar that will attach to the PEPC Cell Housing or the Midplane Transportation Fixture (see AAA97-107575) during operation. While in use in the OAB (Optics Assembly Building), the Spreader Bar Assembly will be manipulated by the NOID (New Optics Insertion Device). The other critical components of the assembly are the three angular contact bearing swivels that attach the spreader bar to the lifting mechanism and the corner clamps which are used to capture the Cell Housing.

Section B: Operational Hazards

The lifting fixture is the only support for the midplane and the PEPC Cell Assembly while it is being manipulated by the NOID. For this reason, it must provide reliable support in all lifting situations. The midplane and its fixture will be well above the ground so there is a critical need for a robust supporting structure. A failure of the unit would represent a probable hazard to personnel and equipment.

Section C: Procedures

The spreader bar was designed for two specific uses. One use is in lifting the midplane transportation fixture, which holds one midplane assembly. The other use is in lifting the PEPC Cell Housing.

When the midplane assembly is to be lifted, the operator shall first establish that the corner clamps/lifting lugs have been removed from the assembly. The midplane will be connected to the spreader bar directly to the bearing swivels using the pins provided along with the bearing swivels.

When the fixture is to lift the PEPC Cell Housing, the corner clamps/lifting lugs MUST be attached. They were designed to seat into the cell housing without damaging the payload. The hex-head bolts used to attach the cell shall be tightened to 45 N-m before every lift. Despite the fact that the fixture has been certified to lift the *mass* of two cell halves at a time, it shall only be used to lift one cell half during normal operation.

Section D: Summary of Safety Factor Calculations

Table 1 lists the calculated safety factors and required safety factor for the static 9-kilonewton design load for the different components of the lifting fixture. The calculations used to arrive at these results can be found in Appendix 3.

Table 1: Safety Factor Calculation Summary for the PEPC Spreader Bar Assy. Subjected to a 9 kN Static Load

Calculation Number	Part Description	Factor of Safety (SF)
<i>For items 3.1.7-3.7, required SF for static loading is >3</i>		
3.1	SPREADER BAR STRESS (Required SF>4)	8.23
3.1.7	SPREADER BAR BUCKLING	3.44
3.2	CROSBY BEARING SWIVELS	14.83
3.3	CORNER CLAMP W/ LIFTING LUG	19.89
3.4	LOCATOR PIN	11.94
3.5	CORNER CLAMP	7.10
3.6	LOAD BEARING HEX SCREW	5.37
3.7	PIVOT PIN	8.45

Table 2 shows the calculated safety factor and required safety factor for the different components of the lifting fixture under 19.89 seismic loading. The calculations used to arrive at these results can be found in Appendix 4.

Table 2: Safety Factor Calculation Summary for the PEPC Spreader Bar Assy. Subjected to a 19.89 kN Seismic Load

Calculation Number	Part Description	Factor of Safety (SF)
<i>For items 4.1.7-4.7, required SF for seismic loading is >1</i>		
4.1	SPREADER BAR STRESS (Required SF>1.25)	3.72
4.1.7	SPREADER BAR BUCKLING	1.56
4.2	CROSBY BEARING SWIVELS	6.71
4.3	CORNER CLAMP W/ LIFTING LUG	8.97
4.4	LOCATOR PIN	5.40
4.5	CORNER CLAMP	3.21
4.6	LOAD BEARING HEX SCREW	3.43
4.7	PIVOT PIN	3.83

Section E: Testing Requirements

The spreader bar shall be load tested to 150% of the design load according to LLNL's M.E. Design Safety Standards. This translates to a load-bearing test of 13.5 kN.

Section F: Labeling Requirements

The Spreader Bar Assembly shall be permanently marked with the following information:

Load Limit: 9 kN [2,023 kips]
Reference: MESN01-092-0A
Use With: PEPC Cell Housing or PEPC Midplane Lifting Fixture

Section G: References

- Marks' Standard Handbook for Mechanical Engineers, 8th Edition, McGraw-Hill, New York (1978).
- Manual of Steel Construction, 8th Edition, American Institute of Steel Construction, Chicago (1980).
- Design Safety Standards – Mechanical Engineering, Rev. 7/Chg. 3 LLNL (1995).
- www.thecrosbygroup.com – 5 July 2001
- Mechanical Engineering Design, 6th Edition, Shigley and Mischke, McGraw-Hill, New York (2001).

Appendix 1: Load Determination

Design Load Calculation

PEPC Spreader Bar Assy (AAA99-109702): 27.691kg

PEPC Cell (Two housings + midplane): 561.056kg
 Midplane Transport Fixture: 78.0kg

****Note:** Since the maximum loading will occur when the spreader bar (S-bar) is loaded with the cell, all calculations will be based upon that situation.

Total Mass of S-bar and cell: 588.746 kg
 Total load (with: $g = 9.81\text{m/s}^2$): $F = 5.776 \text{ kN}$

The design load must be at least 4/3 the estimated average load to minimize the number of “Critical Lifts” that occur (and must be cleared).

$$\begin{aligned} P_0 &= \frac{4}{3} \bullet F \\ P_0 &= 7.70 \text{ kN} \end{aligned}$$

Chose a conservative and easy to work with number around P_0 :

$$\mathbf{P = 9 \text{ kN}}$$

Structure Certification

$$\begin{aligned} P_{\text{load}} &= P - P_{\text{fixture}} \\ P_{\text{load}} &= 9 \text{ kN} - (27.691 \text{ kg}) \bullet (9.81\text{m/s}^2) \\ P_{\text{load}} &= 8.728 \text{ kN} \quad [1.962 \text{ kips}] \end{aligned}$$

Therefore, label the structure as certified to lift up to 1900lbs.

Appendix 2: Material Properties

- Adapted from Rev. 7 of LLNL's ME Design Safety Standards

AL 6061-T6*

Tensile Ultimate: $\sigma_u = 45 \text{ ksi}$
 $\sigma_u = 310.26 \text{ MPa}$

*Note: Because AL6061-T6 is a brittle material, the ultimate stress shall be used in safety factor calculations in order to maintain an acceptable margin for error in the failure calculations. The calculation would not be conservative enough using yield stress.

SST 304

Tensile Yield: $\sigma_y = 34.8 \text{ ksi}$
 $\sigma_y = 240 \text{ MPa}$

STL for Locator/Pivot Pins**

**Since the type of steel is not specified, use the lowest yield strength for steel – Steel A36.

$\sigma_y = 36 \text{ ksi}$
 $\sigma_y = 248.2 \text{ MPa}$

Appendix 3: Static Load Safety Factor Calculations

Note: Supporting figures for the calculations appear directly behind each section of calculations.

3.1 SPREADER BAR (AAA99-109703)

- See attached Shear and Bending-Moment Diagrams for the spreader bar.

3.1.1 Tensile Stress Due to Bending Moment

To find the maximum horizontal tensile stress in the spreader bar it is necessary to express the moment of inertia (MOI) about the horizontal axis of the spreader bar as a function of the horizontal distance from one end of the S-bar. This distance will be called x .

$$\begin{aligned} t &= 0.01905 \text{ m} \\ h(x) &= 0.094708x + 0.099295 \\ I &= \frac{t \cdot h(x)^3}{12} \end{aligned}$$

The horizontal stress can now be determined using the flexure formula.

$$\begin{aligned} M &= -\frac{P \cdot x}{2} && \text{From Bending-Moment Diagram.} \\ c &= \frac{h(x)}{2} \end{aligned}$$

$$\begin{aligned} \sigma_{\max} &= \frac{M \cdot c}{I} \\ \sigma_{\max} &= \frac{\left(-\frac{P \cdot x}{2}\right) \cdot \left(\frac{h(x)}{2}\right)}{\left(\frac{b \cdot h(x)^3}{12}\right)} \\ \sigma_{\max} &= \frac{-3P \cdot x}{b \cdot h(x)^2} \end{aligned}$$

Plug in for $h(x)$ to obtain:

$$\sigma_{\max} = \frac{-3P \cdot x}{(.0089696x^2 + .018808x + .0098595)b}$$

To find σ_{\max} , calculate $\frac{d(\sigma_{\max})}{dx}$ and set it equal to zero. This gives the location of σ_{\max} .

σ_{\max} occurs where $x = 1.048434$ m.

Plugging $x = 1.048434$ into (1) gives:

$$\begin{aligned}\sigma_{\max} &= -4185.5 \bullet P \\ \sigma_{\max} &= 37.68 \text{ MPa}\end{aligned}$$

To be sure, check the endpoints using equation (1):

At the middle: $\sigma_{\max}(1.095) = -4184.5 \bullet P$

At the end: $\sigma_{\max}(0) = 0$

Now calculate the Safety Factor:

$$\begin{aligned}\sigma_u &= 310.26 \text{ MPa} \\ \sigma_{vm} &= 37.68 \text{ MPa}\end{aligned}$$

$$SF = \frac{\sigma_u}{\sigma_{vm}}$$

$$SF = 8.234$$

3.1.2 Shearing Stress

The Shearing Stress (τ) in the S-bar reaches a maximum at the ends of the member (the points where the cross-sectional area are at a minimum). The combined (Von Mises) stresses, however, will reach a maximum near the location of σ_{\max} .

$$|V| = \frac{P}{2} = 4500 \text{ kN}$$

See Shear Diagram

$$t = 0.01905 \text{ m}$$

$$h_s = 0.099295 \text{ m}$$

Smallest cross-section

$$h_0 = 0.19859 \text{ m}$$

Location of maximum tensile stress

$$A = h(x) \cdot t$$

A varies with x

$$\tau_{\max} = \frac{3|V|}{2A}$$

At h_s :

$$\tau_{\max} = \frac{3}{2} \frac{(4500 \text{ kN})}{(0.099295 \text{ m}) \cdot (0.01905 \text{ m})}$$

$$\tau_{\max} = 3.658 \text{ MPa}$$

At h_0 :

$$\tau_{\max} = \frac{3}{2} \frac{(4500 \text{ kN})}{(0.19895 \text{ m}) \cdot (0.01905 \text{ m})}$$

$$\tau_{\max} = 1.784 \text{ MPa}$$

3.1.3 Bearing Stress in Center Supporting Hole

Only analyze the center hole because the other two are geometrically similar and only support half of the load.

$$d = 0.01905 \text{ m}$$

$$\sigma_B = \frac{P}{t \cdot d}$$

$$\sigma_B = \frac{9000 \text{ N}}{(0.01905 \text{ m})(0.0195 \text{ m})}$$

$$\sigma_B = 24.228 \text{ MPa}$$

3.1.4 “Tear-Out” Shear Stress

$$\ell_{T-e} = 0.01565 \text{ m}$$

ℓ_{T-e} is the distance from the tangent of the circle to the edge (conservative for tear-out)

$$\tau_{T-O} = \frac{P}{t \cdot (2\ell_{T-e})}$$

$$\tau_{T-O} = \frac{9000 \text{ N}}{(0.01905 \text{ m})(2)(0.01565 \text{ m})}$$

$$\tau_{T-O} = 15.094 \text{ MPa}$$

Von Mises:

$$\sigma_{vm} = \sqrt{3}\tau_{T-O}$$

$$\sigma_{vm} = 26.144 \text{ MPa}$$

3.1.5 AISC 1.16.5.1

According to the AISC, a hole that is nominally 3/4" in diameter should be 1" from the edge of the part. The top hole and the bottom two holes are nominally 1" from the edge.

$$\ell_{C-e} = 0.02529 \text{ m} = 0.9957" \approx 1 \text{ inch}$$

3.1.6 AISC 1.16.5.2

According to the AISC, “along the line of transmitted force, in the direction of the force, the distance from the center of a standard hole to the edge of the connected part must not be less than: $\frac{2P}{\sigma_y \cdot t} \dots$ ”

$$\ell_{C-e} = 0.02529 \text{ m}$$

ℓ_{C-e} is the distance from the center of the hole to the edge in the vertical direction

$$\ell_{AISC} = \frac{2P}{\sigma_y \cdot t}$$

$$\ell_{AISC} = \frac{2(9000 \text{ N})}{(275.79 \text{ MPa}) \cdot (0.01905 \text{ m})}$$

$$\ell_{AISC} = 0.003426 \text{ m}$$

$$\ell_{C-e} > \ell_{AISC}$$

3.1.7 Critical Buckling Load

- This calculation does not need a Safety Factor of 4.0 because it is not based on the Yield or Ultimate Stress. A safety factor of 3.0 will be used because it is based on the Modulus of Elasticity.
- In order to simplify this calculation, the spreader bar will be modeled as a rectangle with its height equal to the smallest value of the height for the actual spreader bar. This is a very conservative simplification because it neglects a great deal of strengthening material that exists in the structure.
- The problem can be further simplified by cutting the span in half and assuming that the boundary along the cut (vertically in the center of the Bar) is fixed. The actual boundary case does not exactly match this simplification because if the beam were going to fail in the buckling mode the degree of freedom along the normal line to the bar allows the structure to fail earlier than it would if it was a fixed support. Two extremely important strengthening factors that we have neglected in the modeling of the beam counteract this non-conservative simplification.

The first is in the design of the Bearing Swivels. Since the load is directed vertically, the couple caused by a “fold” appearing in the beam will be applied at the load points and will counteract any torsional displacement of the beam. The ability of the Bearing Swivels to resist such forces is included as Figure 3.1.7-Bearing.

In addition, the Cell and the Midplane Lifting Fixture will provide a great deal of rigidity to the structure when they are being lifted. The model that we used assumes that the load is an independent vertical load that is static through a buckling failure. In the real load case, however, the rigidity of the lifted item will act to prevent against buckling.

- See Figure 3.1.7.

$$\ell = 1.095 \text{ m}$$

$$a = -0.02425 \text{ m}$$

$$b = 0.01905 \text{ m}$$

$$d = 0.09930 \text{ m}$$

$$E = 10 \cdot 10^6 \text{ psi} = 68.948 \text{ GPa}$$

$$\nu = .33$$

$$G = \frac{E}{2(1+\nu)}$$

$$G = \frac{68.948 \text{ GPa}}{2(1+.33)}$$

$$G = 25.920 \text{ GPa}$$

From Roark's book, the critical buckling load on a beam having a rectangular cross-section can be expressed as:

$$P' = \frac{0.669 b^3 d \sqrt{\left(1 - 0.63 \frac{b}{d}\right) E G}}{\ell^2} \left[1 - \frac{a}{2\ell} \sqrt{\frac{E}{G \left(1 - 0.63 \frac{b}{d}\right)}} \right]$$

$$\left(1 - .63 \frac{b}{d}\right) = \left(1 - (.63) \left(\frac{0.01905 \text{ m}}{0.09930 \text{ m}}\right)\right) = 0.879$$

$$P' = \frac{0.669(0.01905 \text{ m})^3(0.09930 \text{ m})\sqrt{(0.879)(68.948 \text{ GPa})(25.92 \text{ GPa})}}{(1.095 \text{ m})^2} \dots$$

$$\left[1 - \frac{(-0.02425 \text{ m})}{2(1.095 \text{ m})} \sqrt{\frac{(68.948 \text{ GPa})}{(25.92 \text{ GPa})(0.879)}} \right]$$

$$P' = 15.474 \text{ kN}$$

$$P_{load} = \frac{P}{2} = 4.5 \text{ kN}$$

$$SF = \frac{P'}{P_{load}}$$

$$\mathbf{SF = 3.439}$$

(3.1)

SHEAR AND BENDING-MOMENT PROGRAMS

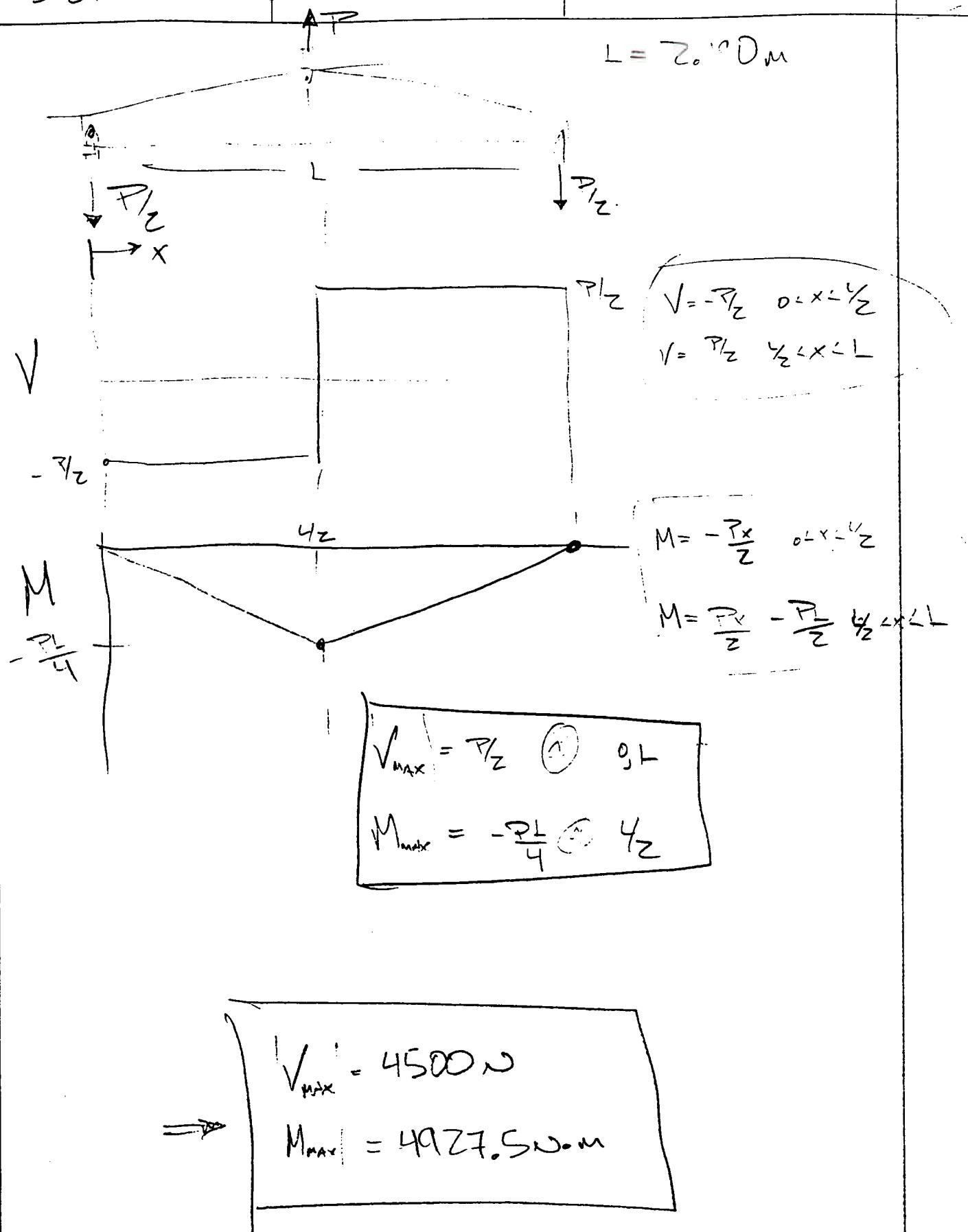


FIGURE 3.1.1, 2, 3

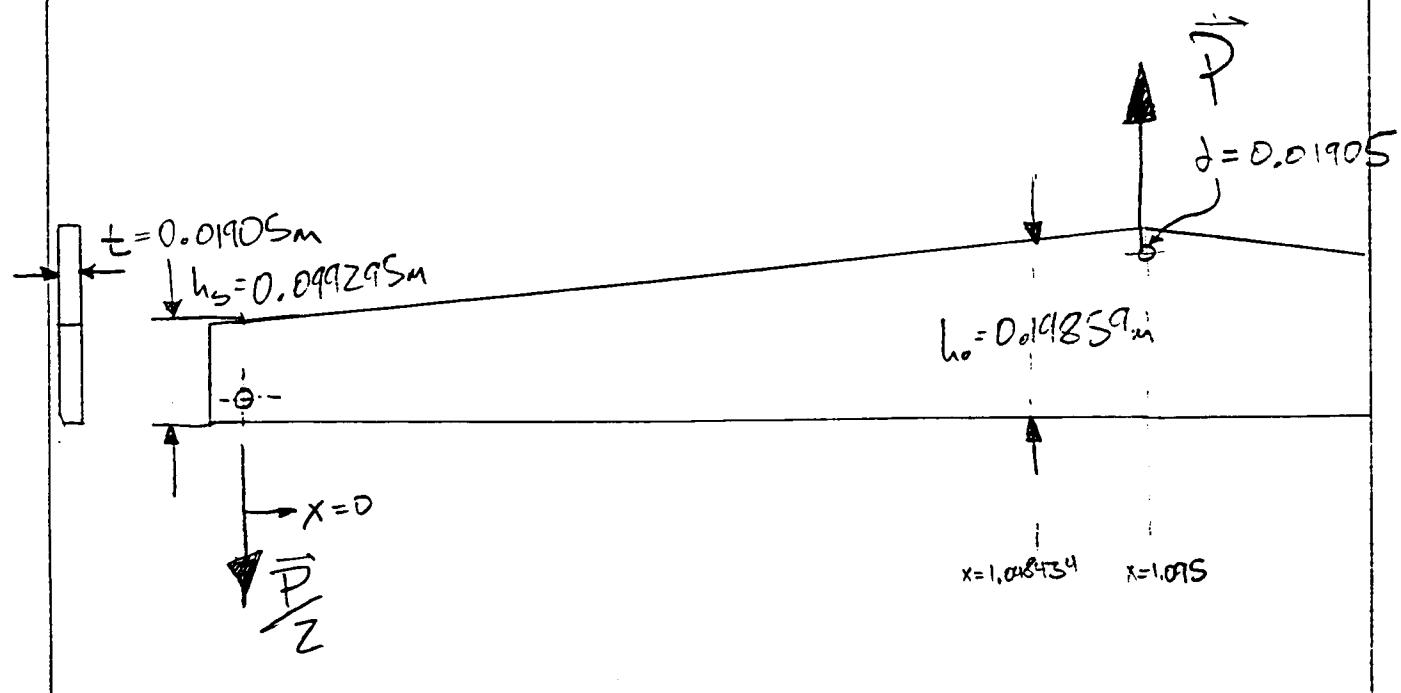


FIGURE 3.1.4, 5, 6

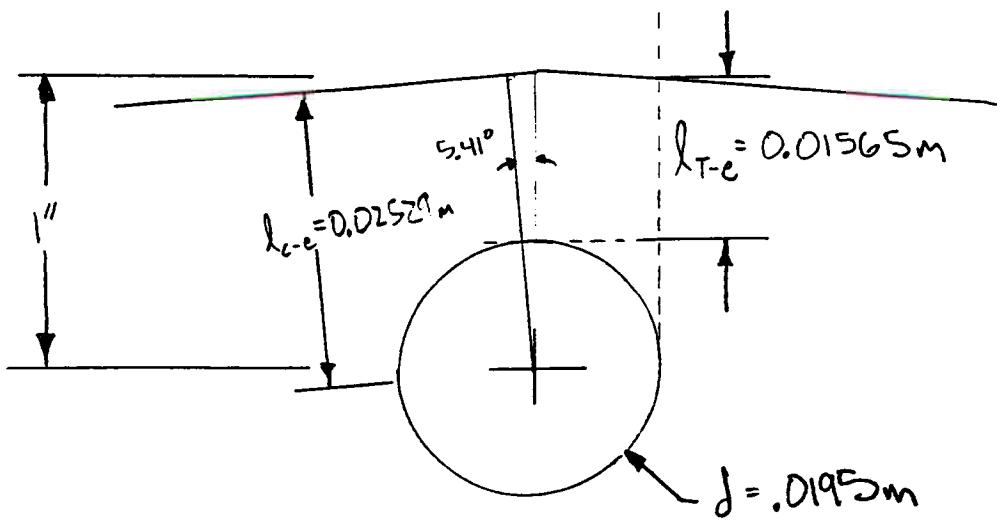


Figure Z-5-6

5-50 • AISC Specification (Effective 11/1/78)

1.16.3 Long Grips

Rivets and A307 bolts which carry calculated stress, and the grip of which exceeds 5 diameters, shall have their number increased 1 percent for each additional $\frac{1}{16}$ -inch in the grip.

1.16.4 Minimum Spacing

1.16.4.1 The distance between centers of standard, oversized, or slotted fastener holes shall be not less than $2\frac{1}{3}d$,* where d is the nominal diameter of the fastener, inches, nor less than that required by Sect. 1.16.4.2, if applicable.

1.16.4.2 Along a line of transmitted force, the distance between centers of holes shall be not less than the following:

1. Standard Holes:

$$2P/F_u t + d/2 \quad (1.16-1)$$

where

P = force transmitted by one fastener to the critical connected part, kips

F_u = specified minimum tensile strength of the critical connected part, kips per square inch

t = thickness of the critical connected part, inches

2. Oversized and Slotted Holes:

The distance required for standard holes in subparagraph 1, above, plus the applicable increment C_1 in Table 1.16.4.2, but the clear distance between holes shall not be less than one bolt diameter.

1.16.5 Minimum Edge Distance

1.16.5.1 The distance from the center of a standard hole to an edge of a connected part shall be not less than the applicable value in Table 1.16.5.1 nor the value from Sect. 1.16.5.2 or 1.16.5.3, as applicable.

1.16.5.2 Along a line of transmitted force, in the direction of the force, the distance from the center of a standard hole to the edge of the connected part shall be not less than

$$2P/F_u t \quad (1.16-2)$$

where P , F_u , and t are as defined in Sect. 1.16.4.2.

1.16.5.3 At end connections bolted to the web of a beam and designed for beam shear reaction only (without use of an analysis which accounts for the effects induced by fastener eccentricity), the distance from the center of the nearest standard hole to the end of the beam web shall be not less than

$$2P_R/F_u t \quad (1.16-3)$$

where P_R is the beam reaction, in kips, divided by the number of bolts, and F_u and t are as defined in Sect. 1.16.4.2. Alternatively, the requirement of Formula (1.16-3) may be waived provided the bearing stress induced by the fastener is limited to not more than $0.90F_u$.

* A distance of $3d$ is preferred. See Commentary Sect. 1.16.4.

Nominal Diameter of Fastener (Inches)
$\leq \frac{7}{8}$
1
$\geq 1\frac{1}{8}$

* When length by the difference

No. Rivet Diameter

* For oversize
b All edge distances does not exceed
c These may be used

Nominal Diameter of Fastener (Inches)
$\leq \frac{7}{8}$
1
$\geq 1\frac{1}{8}$

* When length by one-half

TABLE 1.16.4.2

VALUES OF SPACING INCREMENT C_1 IN SECT. 1.16.4.2, INCHES

Nominal Diameter of Fastener (Inches)	Oversized Holes	Slotted Holes		
		Perpendicular to Line of Force	Parallel to Line of Force	
			Short Slots	Long Slots ^a
$\leq \frac{7}{8}$	$\frac{1}{8}$	0	$\frac{3}{16}$	$\frac{1}{16}d - \frac{1}{16}$
1	$\frac{1}{8}$	0	$\frac{3}{16}$	$\frac{7}{16}$
$\geq 1\frac{1}{4}$	$\frac{1}{4}$	0	$\frac{3}{16}$	$\frac{1}{16}d - \frac{1}{16}$

^a When length of slot is less than maximum allowable (see Table 1.23.4), C_1 may be reduced by the difference between the maximum and actual slot lengths.

(1.16-1)

connected part,

tical connected

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on 1, above, plus
ear distanceto an edge of a
ble 1.16.5.1 norof the force, the
ected part shall

(1.16-2)

TABLE 1.16.5.1
MINIMUM EDGE DISTANCE, INCHES
(CENTER OF STANDARD HOLE^b TO EDGE OF CONNECTED PART)

Nominal Rivet or Bolt Diameter (Inches)	At Sheared Edges	At Rolled Edges of Plates, Shapes or Bars or Gas Cut Edges ^c
$\frac{1}{2}$	$\frac{7}{8}$	$\frac{3}{4}$
$\frac{5}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$
$\frac{3}{4}$	$1\frac{1}{4}$	1
$\frac{7}{8}$	$1\frac{1}{2}$ ^e	$1\frac{1}{8}$
1	$1\frac{3}{4}$ ^e	$1\frac{1}{4}$
$1\frac{1}{8}$	2	$1\frac{1}{2}$
$1\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{1}{8}$
Over $1\frac{1}{4}$	$1\frac{3}{4} \times$ Diameter	$1\frac{1}{4} \times$ Diameter

^a For oversized or slotted holes, see Sect. 1.16.5.4.

^b All edge distances in this column may be reduced $\frac{1}{8}$ -in. when the hole is at a point where stress does not exceed 25% of the maximum allowed stress in the element.

^c These may be $1\frac{1}{4}$ -in. at the ends of beam connection angles.

TABLE 1.16.5.4
VALUES OF EDGE DISTANCE INCREMENT C_2 IN SECT. 1.16.5.4, INCHES

Nominal Diameter of Fastener (Inches)	Oversized Holes	Slotted Holes		
		Perpendicular to Edge		Parallel to Edge
		Short Slots	Long Slots ^a	
$\leq \frac{7}{8}$	$\frac{1}{16}$	$\frac{1}{8}$		
1	$\frac{1}{8}$	$\frac{1}{8}$		
$\geq 1\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{16}$		

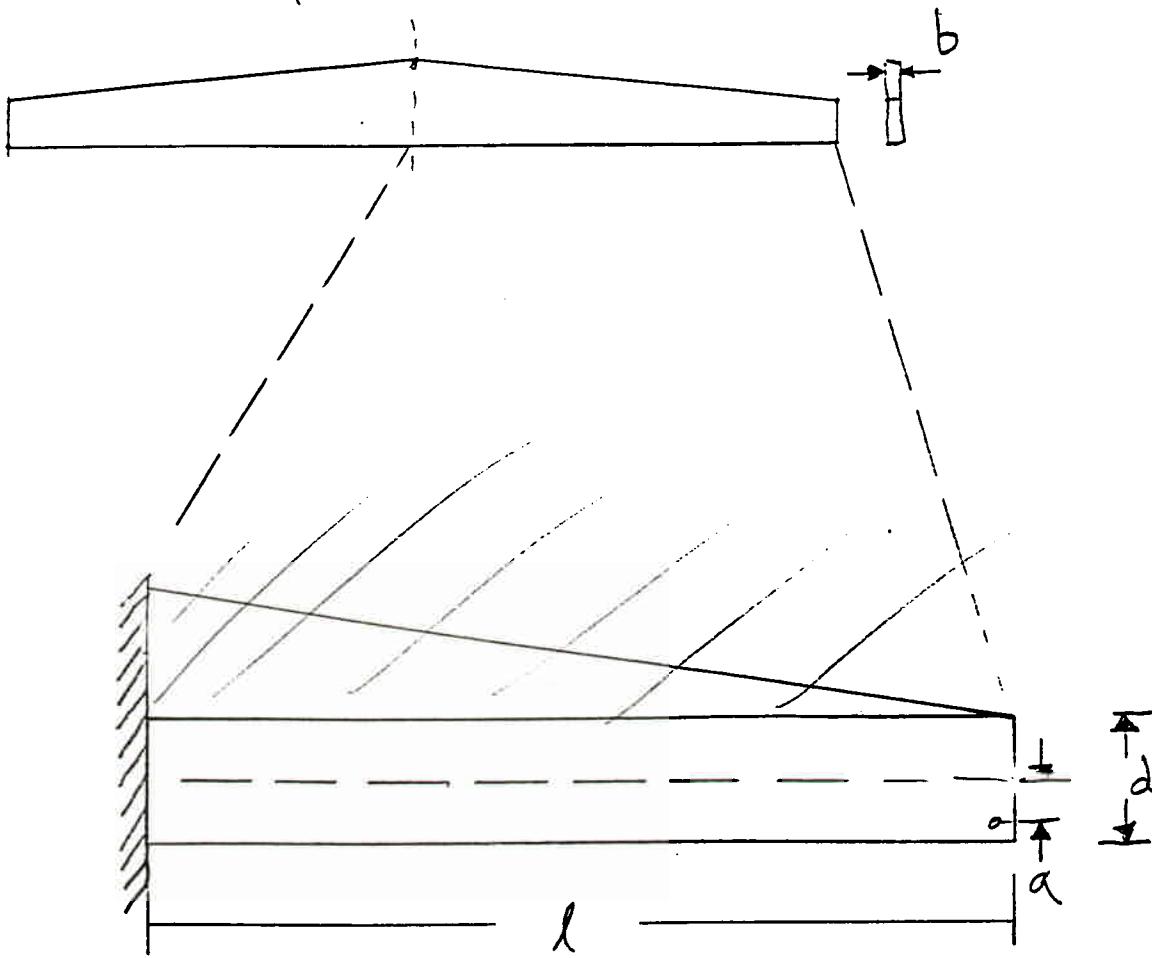
^a When length of slot is less than maximum allowable (see Table 1.23.4), C_2 may be reduced by one-half the difference between the maximum and actual slot lengths.

and designed for
s for the effects
of the nearest

(1.16-3)

ults, and F_u and
nt of Formula
the fastener is

FIGURE 3.17



$$l = 1.095 \text{ m}$$

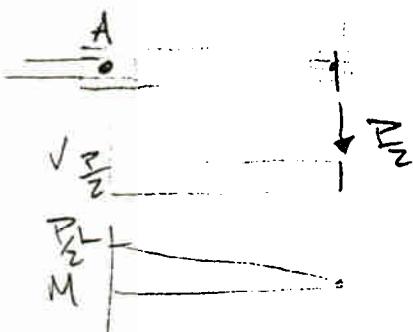
$$a = -0.2425$$

$$b = .01905 \text{ m}$$

$$d = .09930$$

FIGURE 3.1.7 - RETAINING

* THIS IS SUCH AN EXTREME WORST CASE THAT IT IS IMPOSSIBLE. IT, HOWEVER, VERIFIES THAT THE BEARING CAPACITY CAN SUPPORT A COUPLE.



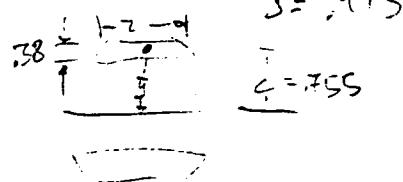
M_{max} occurs at the S-BAR END OF THE BEAM AND HAS A MAG. EQUAL TO $\frac{P_L}{2}$

$$P = 9 \text{ kN} \quad L = 6.25 \text{ m} = .1588 \text{ m} \Rightarrow M = 14.6 \text{ N-m}$$

$$\sigma_y = 65 \text{ ksi} = 448 \text{ kPa}$$

TENDING STRESS:

$$\frac{Mc}{I}$$



$$c = .755 \text{ in} = .0192 \text{ m}$$

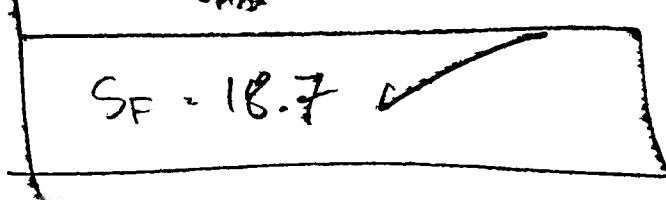
$$I = Z \left(\frac{1}{12} (6 \text{ in}) (38 \text{ in})^3 + (2)(38) (.945)^2 \right)$$

$$I = 1.376 \text{ in}^4 = 5.7274 \times 10^{-7} \text{ m}^4$$

$$\sigma_{max} = \frac{(714.6 \text{ N.m})(.0192 \text{ m})}{5.7274 \times 10^{-7} \text{ m}^4}$$

$$\sigma_{max} = 23.96 \text{ kPa}$$

$$\Rightarrow SF = \frac{\sigma_y}{\sigma_{max}} = \frac{448 \text{ kPa}}{23.96 \text{ kPa}}$$



3.2 CROSBY BEARING SWIVELS (N4030-17446 and N4030-17504)

Calculate acceptability based on the Jaw and Eye swivel only because the Jaw and Jaw swivels have the same capacity and only carry half of the load.

$$\text{Working Load Limit} = P_w = 3 \text{ Tons} = 6000 \text{ lb}_f = 26.689 \text{ kN}$$
$$P = 9 \text{ kN} \Rightarrow P < P_w$$

$$\text{Ultimate Load} = P_{ULT} = 5 P_w = 133.445 \text{ kN}$$

$$SF = \frac{P_{ULT}}{P}$$

$$SF = \frac{(133.445 \text{ kN})}{(9 \text{ kN})}$$

$$SF = 14.827$$

The Bearing Swivels are, therefore, acceptable for two reasons:

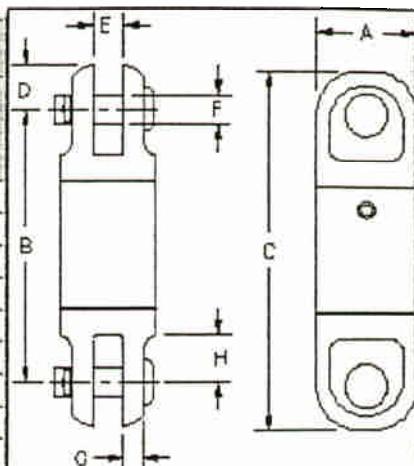
- The Load (P) is less than the Working Load Limit (P_w)
- The Ultimate Load is high enough to provide an acceptable safety factor when the member is loaded.

**Note: The manufacturers data also takes the pins into account so there is no need to perform the calculations for the shearing in the pins and the tensile/shearing in the pin holes.

Crosby® Angular Contact Bearing Swivels

Page 124

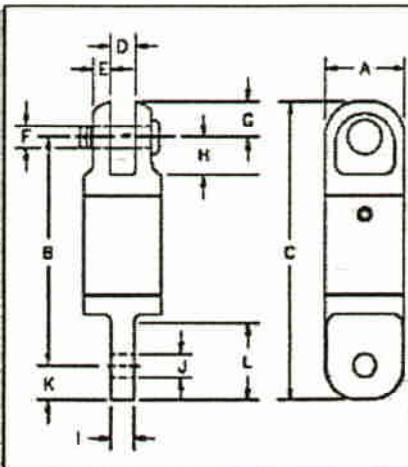
AS-2 JAW & JAW				Dimensions (in.)							
Working Load Limit* (tons)	Wire Line Size (in.)	AS-2 Stock No.	Weight Each (lbs.)	A	B	C	D	E	F	G	H
.45	1/8	1016103	.4	.88	2.38	3.13	.38	.25	.25	.19	.41
.75	1/4	1016114	.9	1.31	3.56	4.44	.44	.31	.38	.22	.56
1.5	3/8	1016122	2.0	1.63	4.06	5.44	.69	.50	.50	.28	.78
3.0	1/2	1016131	4.9	2.00	6.25	8.13	.94	.75	.75	.38	1.19
5.0	5/8	1016139	9.6	2.50	7.75	10.63	1.13	1.00	.88	.53	1.53
8.5	3/4	1016148	15.8	3.00	9.63	12.31	1.34	1.56	1.19	.56	2.09
10	7/8	1016157	40.0	4.00	14.00	17.50	1.75	1.75	1.50	.81	3.50
15	1	1016166	40.0	4.00	14.00	17.50	1.75	1.75	1.50	.81	3.50
25	1-1/4	1016175	78.0	5.00	15.94	20.69	2.38	2.00	2.03	1.13	3.69
35	1-1/2	1016184	78.0	5.00	15.94	20.69	2.38	2.00	2.03	1.13	3.69



AS-2

* Ultimate Load is 5 times the Working Load Limit.

AS-3 JAW & EYE				Dimensions (in.)											
Working Load Limit* (tons)	Wire Line Size (in.)	AS-3 Stock No.	Weight Each (lbs.)	A	B	C	D	E	F	G	H	I	J	K	L
.45	1/8	1016205	.3	.88	2.50	3.25	.25	.19	.25	.38	.41	.25	.25	.38	.84
.75	1/4	1016216	.9	1.31	3.69	4.56	.31	.22	.38	.44	.56	.31	.38	.44	.88
1.5	3/8	1016224	1.9	1.63	4.19	5.44	.50	.28	.50	.69	.78	.50	.66	.63	1.38
3.0	1/2	1016232	4.6	2.00	6.19	8.13	.75	.38	.75	.94	1.19	.75	.91	1.00	2.00
5.0	5/8	1016243	9.1	2.50	7.88	10.19	1.00	.53	.88	1.13	1.50	1.00	1.25	1.19	2.63
8.5	3/4	1016250	15.6	3.00	9.50	12.25	1.56	.56	1.25	1.34	2.09	1.25	1.41	1.50	3.13
10	7/8	1016259	39.0	4.00	13.75	17.31	1.75	.81	1.50	1.75	3.50	2.00	1.63	1.81	4.69
15	1	1016268	40.0	4.00	13.44	17.31	1.75	.81	1.50	1.75	3.50	2.00	2.00	2.13	4.69
25	1-1/4	1016277	78.0	5.00	16.00	20.75	2.00	1.13	2.00	2.38	3.69	2.25	2.31	2.38	5.25
35	1-1/2	1016286	78.0	5.00	16.00	20.75	2.00	1.13	2.00	2.38	3.69	2.25	2.31	2.38	5.2



AS-3

* Ultimate Load is 5 times the Working Load Limit.

3.3 CORNER CLAMP W/ LIFTING LUG (AAA99-109705)

3.3.1 Tensile Stress

$$d = 0.0195 \text{ m}$$

$$t = 0.01905 \text{ m}$$

$$A_T = t(0.045 - d) = (0.01905)(0.045 - 0.0195) = 4.8578 \cdot 10^{-4} \text{ m}^2$$

$$\sigma_T = \frac{P}{2A_T}$$

$$\sigma_T = \frac{9000 \text{ N}}{(2)(4.8578 \cdot 10^{-4} \text{ m}^2)}$$

$$\sigma_T = 9.263 \text{ MPa}$$

3.3.2 Bearing Stress

$$\sigma_B = \frac{P}{2t \cdot d}$$

$$\sigma_B = \frac{9000 \text{ N}}{2(0.01905 \text{ m}) \cdot (0.0195 \text{ m})}$$

$$\sigma_B = 12.114 \text{ MPa}$$

$$\sigma_Y = 240 \text{ MPa}$$

$$SF = \frac{\sigma_Y}{\sigma_B}$$

$$SF = 19.894$$

3.3.3 “Tear-Out” Shearing Stress

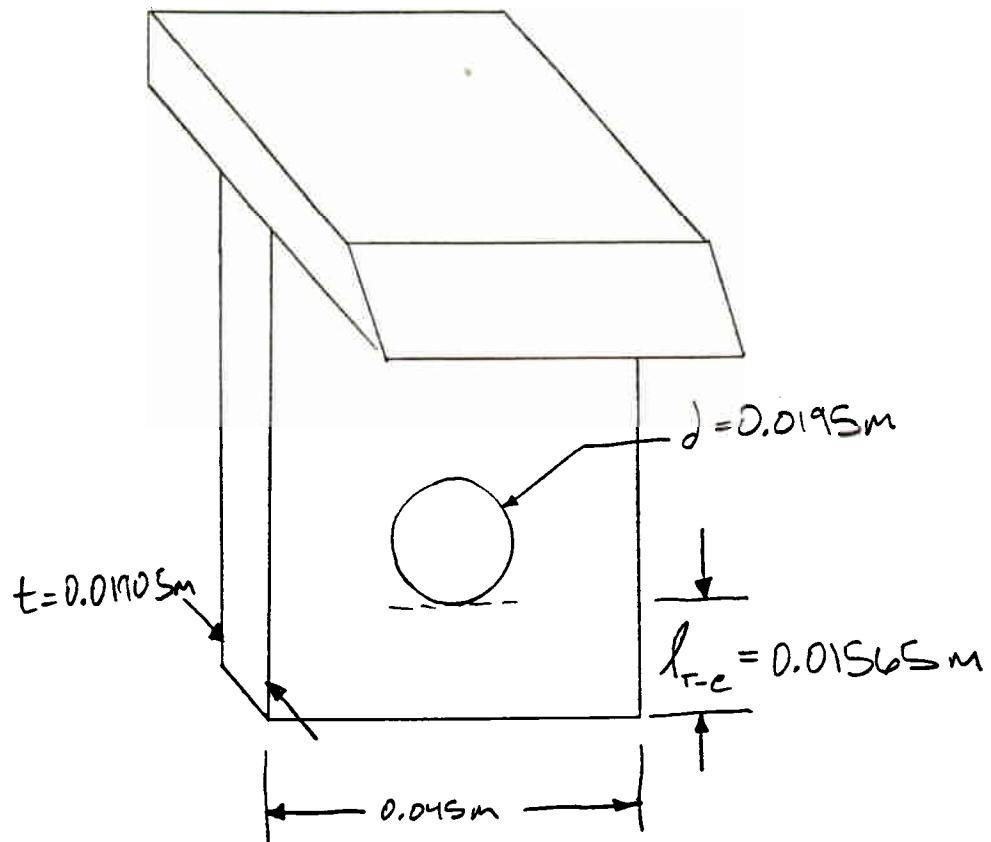
$$\ell_{T-e} = 0.01565 \text{ m}$$

$$\tau_{T-O} = \frac{P}{t \cdot (2\ell_{T-e})}$$

$$\tau_{T-O} = \frac{9000 \text{ N}}{(0.01905 \text{ m})(2)(0.02428 \text{ m})}$$

$$\tau_{T-O} = 9.729 \text{ MPa}$$

FIGURE 3.3



3.4 LOCATOR PIN (AAA99-109705-01)

3.4.1 Shearing

$$\ell = 0.0375 \text{ m}$$

ℓ is the length of the pin minus the diameter of the hole bored into it

$$d = 0.01 \text{ m}$$

$$A = \ell \cdot d$$

$$\tau = \frac{V}{A}$$

$$\tau = \frac{P}{2\ell \cdot d}$$

$$\tau = \frac{9000 \text{ N}}{2(0.0375 \text{ m}) \cdot (0.01 \text{ m})}$$

$$\tau = 12.0 \text{ MPa}$$

Von Mises:

$$\sigma_{\text{vm}} = \sqrt{3}\tau$$

$$\sigma_{\text{vm}} = 20.785 \text{ MPa}$$

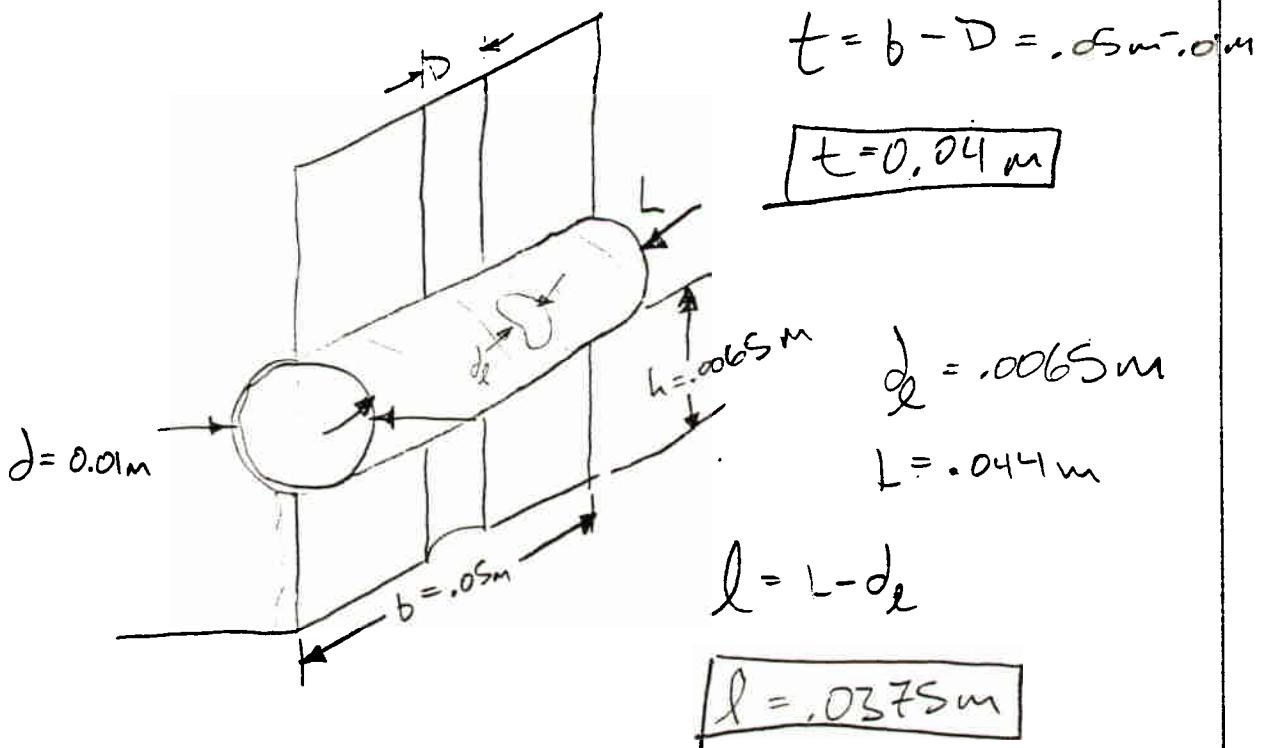
$$\sigma_y = 248.2 \text{ MPa}$$

$$SF = \frac{\sigma_y}{\sigma_{\text{vm}}}$$

$$SF = 11.942$$

FIGURE 3.45

$$D = .01m$$



3.5 CORNER CLAMP (AAA99-109704)

3.5.1 Shearing Due to Locator Pin

- Assume the shearing occurs along a line close to the edge of a part.

$$h = 0.0065 \text{ m}$$

*h is the minimum height of the section that is acted on by the pin
t is the thickness of that material, minus the diameter of the through hole in it.*

$$\tau = \frac{V}{A}$$

$$\tau = \frac{P}{2t \cdot h}$$

$$\tau = \frac{9000 \text{ N}}{2(0.040 \text{ m}) \cdot (0.0065 \text{ m})}$$

$$\tau = 17.308 \text{ MPa}$$

Von Mises:

$$\sigma_{vm} = \sqrt{3}\tau$$

$$\sigma_{vm} = 29.978 \text{ MPa}$$

3.5.2 Bearing Stress Due to Locator Pin

- Assume the pin acts over only 1/3 its diameter instead of 1/2 due to the geometry of the part.

$$d = \frac{D}{3} = 0.00333 \text{ m}$$

$$t = .04 \text{ m}$$

$$\sigma_b = \frac{P}{2t \cdot d}$$

$$\sigma_b = \frac{9000 \text{ N}}{2(0.04 \text{ m}) \cdot (0.00333 \text{ m})}$$

$$\sigma_b = 33.784 \text{ MPa}$$

$$\sigma_y = 240 \text{ MPa}$$

$$SF = \frac{\sigma_y}{\sigma_b}$$

$$SF = 7.104$$

UNCLASSIFIED

**26 M30 5.6M
T9 DRILL THRU
T9 MIN TND
Φ 0.161.005[ABC]**

**VIEW FOR ROLL ONLY
SCALE 1:000**

NOTES. UNLESS OTHERWISE SPECIFIED

101. ALL DIMENSIONS ARE IN MILLIMETERS AND VALUES ARE IN SI UNITS. CUSTOMARY UNITS (IN BRACKETS) ARE IN INCHES. DIMENSIONS AND VALUES FROM MILLIMETERS / SI UNITS CONVERTED FROM INCHES.

102. APPLICABLE STANDARDS AND SPECIFICATIONS:

- SME Y14.5M-1984, Dimensioning and Tolerancing
- ASME Y14.1, Abbreviations
- ASME Y14.16, Surface Texture Symbols
- ANSI Y14.2, Standard Symbols for Welding

103. 1.6 (13) FINISH ALL MACHINED SURFACES PER ASME B4.6.

104. REMOVE ALL BURRS AND INHOLE UNITS 0.75 mm (0.03 in) to 1.0 to 1.5 mm (0.10 in) IN LENGTH OR RADII. RADII MUST MAKE A SMOOTH TRANSITION WITH ADJACENT SURFACES.

105. PERMANENTLY MARK PART PER MIL STD-130 WITH DRAWING NUMBER, REVISION LETTER, AUTHORITY NUMBER, SERIAL NUMBER IF APPLICABLE, AND DATE OF MANUFACTURE. MARKING SHALL BE APPROVED BY LINE PRIOR TO MARKING PART.

106. INSPECTION / ACCEPTANCE TO BE MEASURED AND RECORDED IN SI UNITS.

107. ESTIMATED WEIGHT IS 0.411 kg (0.90 lb).

108. ESTIMATED SURFACE AREA IS 14.796 cm² (22.934 in²).

109. FABRICAL, CLEAN AND PACKAGE, GEAR, MECHANICAL, AND ELECTRONIC FABRICATION AND HANDLING OF W/F LASER COMPONENTS AND STRUCTURES.

110. APPLICABLE STANDARDS AND SPECIFICATIONS: FOR MANUFACTURING.

111. ISO 174-2, METRIC SCREW THREADS.

112. THIS DRAWING WAS CREATED BY THE UNIVERSITY OF CALIFORNIA AND OPERATES LAWRENCE LIVERMORE NATIONAL LABORATORY FOR THE U.S. DEPARTMENT OF ENERGY. THIS DRAWING IS THE PROPERTY OF THE U.S. GOVERNMENT AND IS NOT FOR RELEASE TO THE PUBLIC WITHOUT THE PERMISSION OF UCRL.

UNCLASSIFIED

SECTION A-A

SECTION B-B

NIF PRODUCTION RELEASE

WBS 13.3

**LAWRENCE LIVERMORE NATIONAL LABORATORY
A DIVISION OF THE NATIONAL SECURITY AGENCY**

WBS 13.3-0

OB: WORKSTATION 01

PCPC SPREADER BAR ASSEMBLY

CORNER CLAMP

WBS 13.3-1

UNCLASSIFIED

SECTION C-C

SECTION D-D

SECTION E-E

SECTION F-F

SECTION G-G

SECTION H-H

SECTION I-I

SECTION J-J

SECTION K-K

SECTION L-L

SECTION M-M

SECTION N-N

SECTION O-O

SECTION P-P

SECTION Q-Q

SECTION R-R

SECTION S-S

SECTION T-T

SECTION U-U

SECTION V-V

SECTION W-W

SECTION X-X

SECTION Y-Y

SECTION Z-Z

3.6 LOAD BEARING HEX SCREW (N5305-10215)

3.6.1 Thread Engagement

- See Figure 3.6

Calculate the acceptable thread engagement (e) as it is related to the diameter (D) of the screw and compare with the ME DSS prescribed values.

$$\begin{aligned} L &= 0.035 \text{ m} && \text{Length of Screw (L)} \\ D &= 0.01 \text{ m} \end{aligned}$$

The interior threads begin at a hole depth of 0.01465 m below the bottom of the screw head.

$$\begin{aligned} e &= L - .01465 \text{ m} \\ e &= .02035 \text{ m} \end{aligned}$$

$$e = 2.061xD$$

According to the ME DSS, the maximum thread engagement that is necessary in order to avoid a thread failure for a metal bolt is 2.0xD. Therefore, the screw has an acceptable number of threads engaged.

3.6.2 Axial Bolt Force due to Worst-Case Loading

- See Figure 3.6 for an explanation of the worst case.

$$a = 0.05445 \text{ m}$$

$$b = 0.02 \text{ m}$$

$$c = 0.2682 \text{ m}$$

$$F_w = \frac{\left(\frac{P}{2}\right)}{\left(\cos 5.739^\circ\right)}$$

$$F_w = \frac{(4.5 \text{ kN})}{\left(\cos 5.739^\circ\right)}$$

$$F_w = 4.523 \text{ kN}$$

$$F_{w_x} = 3.502 \text{ kN}$$

$$F_{w_y} = 2.862 \text{ kN}$$

$$\sum M_A = 0 = F_{\text{bolt}} \cdot b + F_{w_y} \cdot c - F_{w_x} \cdot a$$

$$F_{\text{bol}} = \frac{F_{w_x} \cdot a - F_{w_y} \cdot c}{b}$$

$$F_{\text{bolt}} = \frac{(3.502 \text{ kN})(0.05445 \text{ m}) - (2.862 \text{ kN})(0.02682 \text{ m})}{(0.02 \text{ m})}$$

$$F_{\text{bolt}} = 5.696 \text{ kN} = F$$

$$A_B = 2 \left(\frac{\pi D^2}{4} \right) \quad \text{Area calculated for 2 bolts/corner}$$

$$A_B = \frac{\pi (0.01 \text{ m})^2}{2}$$

$$A_B = 1.5708 \cdot 10^{-4} \text{ m}^2$$

$$F_s = F_{W_y} = 2.862 \text{ kN}$$

$$\sigma_{\text{vm}} = \left(\frac{1}{A_B} \right) \sqrt{F^2 + 3F_s^2}$$

$$\sigma_{\text{vm}} = \left(\frac{1}{1.5708 \cdot 10^{-4}} \right) \sqrt{(4.980 \text{ kN})^2 + 3 \cdot (2.862 \text{ kN})^2}$$

$$\sigma_{\text{vm}} = 44.733 \text{ MPa}$$

$$\sigma_Y = 240 \text{ MPa}$$

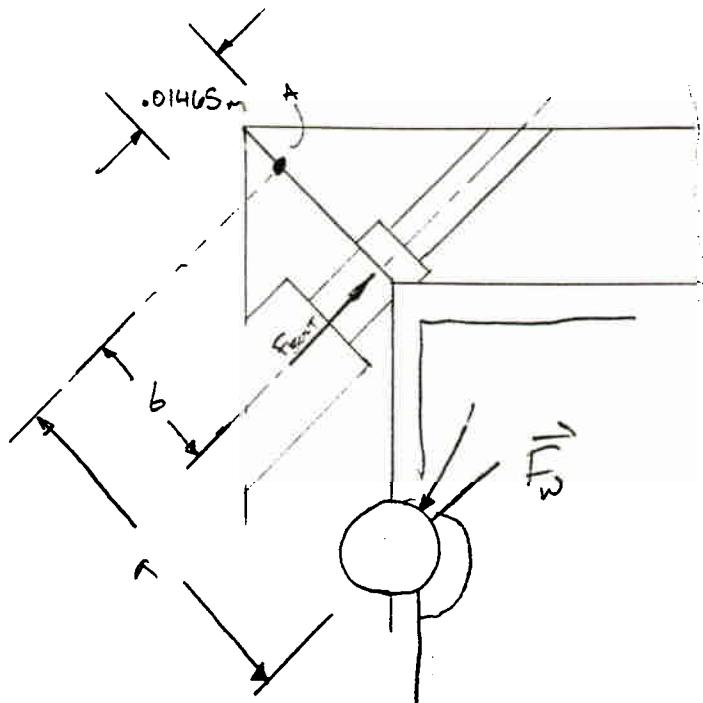
$$SF = \frac{\sigma_Y}{\sigma_{\text{vm}}}$$

$$SF = 5.365$$

FIGURE 3.6

$$b = .02 \text{ m}$$

$$a = .05445 \text{ m}$$



$$a = 61 \cos 45^\circ + 16 \cos 45^\circ$$

$$a = 54.45 \text{ mm}$$

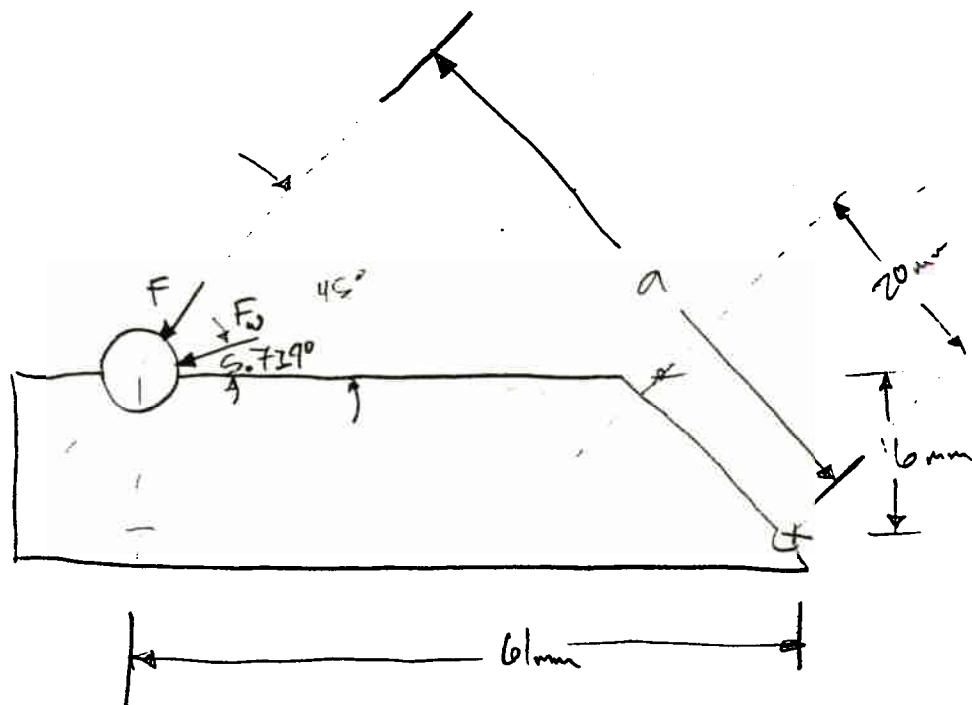
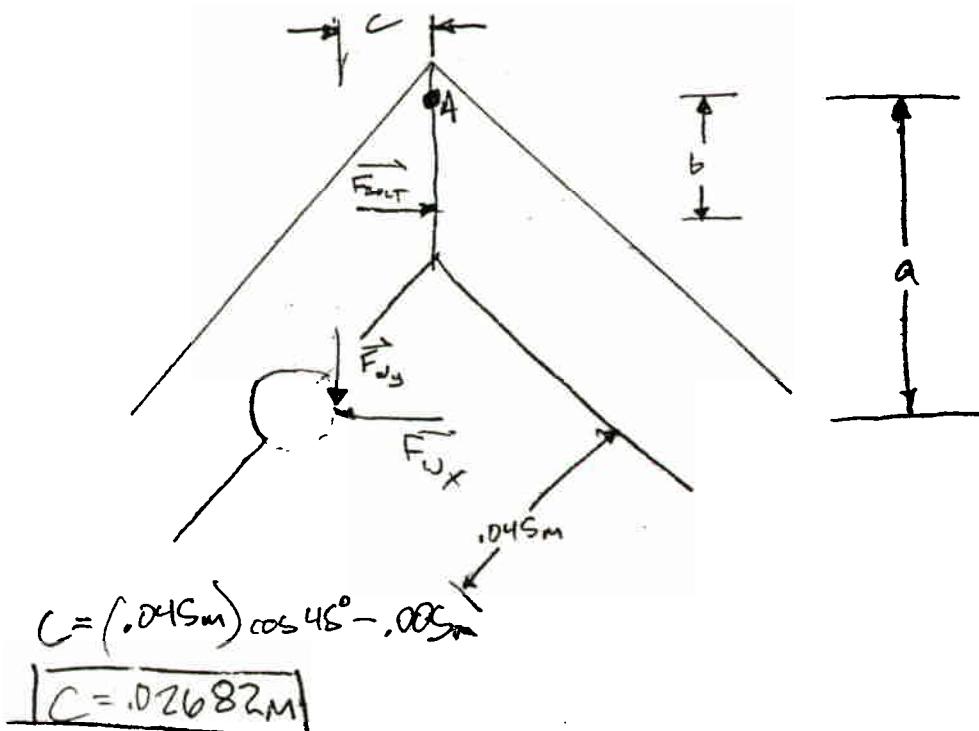
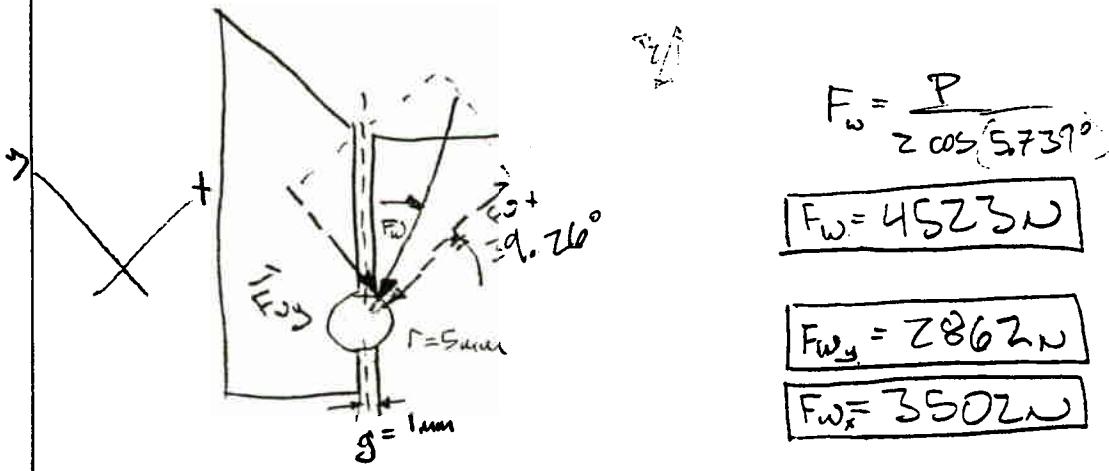


FIGURE 3.6 (cont)

THE WORST CASE OCCURS WHEN THE TWO SLOTS FOR THE LOCATOR PIN ARE AT THEIR SMALLEST DIMENSION



$$\sum M_h = 0 = F_{SOLT} \cdot b + F_{w_y} \cdot C - F_{w_x} \cdot a$$

$$F_{SOLT} = - \frac{(2862 N)(.02682 m) + (3502 N)(.05446 m)}{(.02 m)}$$

$F_{SOLT} = 5696 N$

Figure 3. U-N505

NIF QUALITY STANDARDS PROGRAM LIST OF ACCEPTABLE BRANDS

QS Number 10015 Rev. AI

Page 1 of 5

QS Review Date _____ Initials _____

Revision Date 5/26/01

Quantity of NIF-3841 Reports 2

NIF Catalog Number(s): Group Class N5305- (See pages 2-4)

NIF Item Description: Screw, hexagon socket head cap, Grade A2/A4, Property Class 70, stainless steel, standard (coarse) threads, dimensions per DIN 912/ISO 4762.

Minimum Requirements: 1) Per description. 2) See pages 2-5, 3) Manufacturer and grade markings shall appear on all screws with a diameter of M5 and above, 4) Use only the approved distributors listed on the 3841's

Other Information: A2 stainless steel is similar to 304 alloy and A4 is similar to 316 alloy.

Established by: F. Mahler Phon 3-6752 Date 5/26/01

(Initials) e

Site: 1 Department/Standards Group: NIF-CE Technical Responsibility: NIF-CE

Name	Initials	Phone	Group	Date
------	----------	-------	-------	------

Reviewed by: _____

Approved by: F. Mahler Phon 3-6752 Date 5/26/01

Project Management: _____

The manufacturer(s)/brand(s) listed below are the only known brand(s) acceptable to meet minimum requirements. Test and/or evaluation results are available at the above stated department/standards group and/or are contained on form NIF-3841 attached hereto as part of this file.

Mfgr. Name	Brand, Series, Model or Part No.	F/PF*	Added by	Date	NIF-3841 Report No.
1. <u>Bossard</u>	<u>BN 610, 611, 612, 613</u> <u>Series</u>	<u>F</u>	<u>F. Mahler</u>	<u>9/1/98</u>	<u>1</u>
2. <u>Fabory USA Ltd</u>	<u>51050, 55050 Series</u>	<u>F</u>	<u>F. Mahler</u>	<u>9/1/98</u>	<u>2</u>
3.					
4.					
5.					
6.					
7.					
8.					

*F = Known foreign manufacturer
PF = Possible foreign manufacturer

3.7 PIVOT PIN (AAA97-100278)

3.7.1 Shearing Stress due to Bolt Loading

- See Figure 3.6 for an explanation of the worst case.

$$F_{W_x} = 3.502 \text{ kN}$$

$$F_{W_y} = 2.862 \text{ kN}$$

$$F_{\text{bolt}} = 4.980 \text{ kN}$$

$$F_{\text{PIV}_x} = F_{\text{BOLT}} - F_{W_x}$$

$$F_{\text{PIV}_x} = 4.980 \text{ kN} - 3.502 \text{ kN}$$

$$F_{\text{PIV}_x} = 1.478 \text{ kN}$$

$$F_{\text{PIV}_y} = F_{W_y}$$

$$F_{\text{PIV}_y} = 2.862 \text{ kN}$$

$$F_{\text{PIV}} = \sqrt{(F_{\text{PIV}_x})^2 + (F_{\text{PIV}_y})^2}$$

$$F_{\text{PIV}} = 3.221 \text{ kN}$$

$$h = 0.005 \text{ m}$$

$$t = 0.038 \text{ m}$$

*h is the diameter of the pin
t is length of the pin, minus the diameter of
the two through holes in it.*

$$\tau = \frac{F_{\text{PIV}}}{A}$$

$$\tau = \frac{F_{\text{PIV}}}{t \cdot h}$$

$$\tau = \frac{3.221 \text{ kN}}{(0.038 \text{ m})(0.005 \text{ m})}$$

$$\tau = 16.953 \text{ MPa}$$

Von Mises:

$$\sigma_{vm} = \sqrt{3}\tau$$

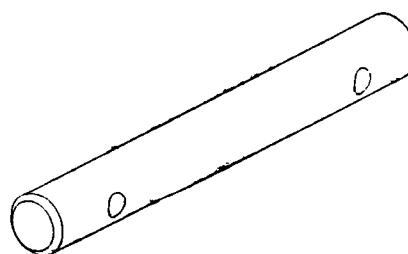
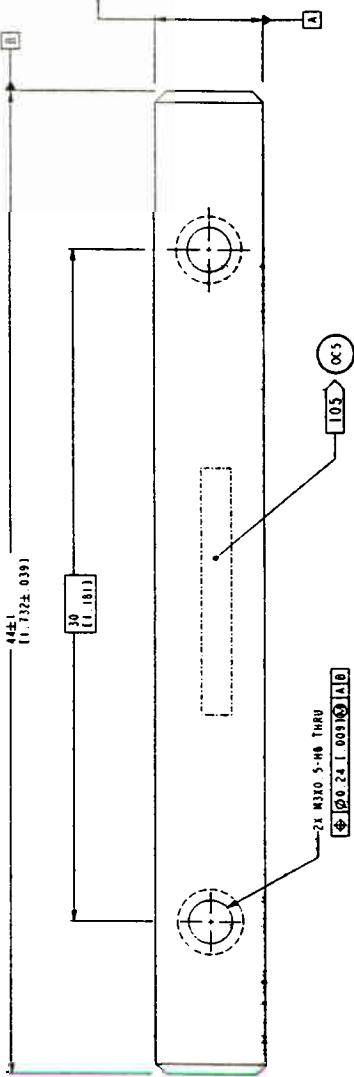
$$\sigma_{vm} = 29.363 \text{ MPa}$$

$$\sigma_Y = 248.2 \text{ MPa}$$

$$SF = \frac{\sigma_Y}{\sigma_{vm}}$$

$$SF = 8.453$$

Classification	UNCLASSIFIED
4	4
5	5
6	6
7	7
8	8
9	9
0	0



NOTE: UNLESS OTHERWISE SPECIFIED

(1) ALL DIMENSIONS ARE IN MILLIMETERS AND VALUES ARE IN
SI UNITS. + VALUES ARE IN BRAKETED IN MILLIMETERS / .5
INCHES.

(2) APPLICABLE STANDARDS AND SPECIFICATIONS
ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING
ASME Y14.35M SURFACE TEXTURE SYMBOLS

- (3) 1.6 (16) FINISH ALL MACHINED SURFACES PER ASME Y14.35.
 (OC1) 104. REMOVE ALL BURRS AND BREAK EDGES 0.25 mm 1.00 in.
 (OC1) 105. MUST MAKE A SMOOTH TRANSITION IN ADJACENT SURFACES.
 (OC1) 106. PERMANENTLY MARK PART PER MIL STD 110 MIN DRAWING
 NUMBER REVISION LETTER, LABORATORY NUMBER,
 SERIAL NUMBER, AND FABRICATOR NUMBER WHICH SHOWN
 IN DRAWING. A 1 mm CHARACTER MARKING IS
 TO BE APPROVED BY LINE PRIOR TO MARKING PART.

- (OC1) 107. ESTIMATED WEIGHT 15.6 435 g 1.0 279 oz.
 (1) ESTIMATED SURFACE AREA 15.167 9.14 m² 11.438 ft².
 (OC1) 112. FABRICATE PART PER WBS 133-001 FABRICATION OF RIF LASER
 COMPONENTS AND STRUCTURE.

- (4) APPLICABLE STANDARDS AND SPECIFICATIONS FOR MANUFACTURING
 1.50 in. min. GAGE SWEEP THICKNESS.
 102. ELECTROLESS NICKEL PLATE PART PER AM-2404 FOR HEAT
 TREATABLE METALS, 0.04 mm 1.015 in.
 MINIMUM THICKNESS PLATE. PRIOR TO INSTALLING INSERTS
 AND MASH OFF ALL TAPPED HOLES IF APPLICABLE. AFTER
 PLATING, KINETIC, AND DRYING, PART SHALL BE HEATED AT
 400°C ± 5°C 750°F ± 5°F FOR NOT LESS THAN 90 MIN. ALL
 DIMENSIONS APPLY AFTER PLATING.

AMAG7-N00278-0C
00000000000000000000000000000000

CLASSIFICATION		UNCLASSIFIED	
REF ID:	WBS 133	REF ID:	WBS 133
REF ID:	WBS 133	REF ID:	WBS 133

FOR REF ONLY

SCALE 6.000

DATE: 08/01/2000
DRAWN BY: J. H. GUY
DESIGNED BY: J. H. GUY
REVIEWED BY: J. H. GUY
APPROVED BY: J. H. GUY
PRINTED BY: J. H. GUY
PRINT DATE: 08/01/2000

Appendix 4: Seismic Load Safety Factor Calculations

The hazard category for this equipment is Category 1b, moderate or low hazard facility. This category was chosen for this lifting fixture because a failure could result in considerable onsite personnel impact, but little environmental impact. For this category, seismic accelerations are $H=V=0.57$ and the amplification factor is 2.12.

$$V = (0.57)(2.12) = 1.21$$

This leads to a total seismic load of:

$$\begin{aligned} P_s &= 9.0 \text{ kN} + (1.21)(9.0 \text{ kN}) \\ P_s &= 19.89 \text{ kN} \end{aligned}$$

Since the fixture is mounted such that it is free to swing in the horizontal direction, the only critical seismic force is in the vertical direction. There is no risk of tipping with the spreader bar assembly.

The calculations can be simplified by realizing that the change in load effects the results of the static loading case in a strictly linear manner. So, all shearing and tensile stresses will simply be multiplied by the absolute seismic amplification factor (f_{AS}).

$$f_{AS} = 2.21$$

4.1 SPREADER BAR (AAA99-109703)

- See attached Shear and Bending-Moment Diagrams for the spreader bar.

$$\begin{aligned} \sigma_{max} &= 37.68 \text{ MPa} \\ \tau_{max} &= 1.784 \text{ MPa} \end{aligned}$$

Amplified values:

$$\begin{aligned} \sigma_{AMP} &= 83.273 \text{ MPa} \\ \sigma_Y &= 275.79 \text{ MPa} \end{aligned}$$

$$\begin{aligned} SF &= \frac{\sigma_Y}{\sigma_{AMP}} \\ SF &= 3.312 \end{aligned}$$

AISC 1.16.5.2

According to the AISC, “along the line of transmitted force, in the direction of the force, the distance from the center of a standard hole to the edge of the connected part must not be less than: $\frac{2P}{\sigma_y \cdot t} \dots$ ”

$$\ell_{C-e} = 0.02529 \text{ m}$$

$$\ell_{AISC} = \frac{2P_s}{\sigma_y \cdot t}$$

$$\ell_{AISC} = \frac{2(19890 \text{ N})}{(275.79 \text{ MPa}) \cdot (0.01905 \text{ m})}$$

$$\ell_{AISC} = 0.007572 \text{ m}$$

$$\ell_{C-e} > \ell_{AISC}$$

4.1.7 Critical Buckling Load

$$P' = 15.474 \text{ kN}$$

$$P_s = 19.89 \text{ kN}$$

As shown in 3.1.7

$$P_{load} = \frac{P_s}{2} = 9.945 \text{ kN}$$

$$SF = \frac{P'}{P_{load}}$$

$$SF = 1.556$$

4.2 CROSBY BEARING SWIVELS (N4030-17446 and N4030-17504)

Calculate acceptability based on the Jaw and Eye swivel only because the Jaw and Jaw swivels have the same capacity and only carry half of the load.

$$\text{Working Load Limit} = P_w = 3 \text{ Tons} = 6000 \text{ lb}_f = 26.689 \text{ kN}$$

$$P_s = 19.89 \text{ kN} \Rightarrow P_s < P_w$$

$$\text{Ultimate Load} = P_{ULT} = 5 P_w = 133.445 \text{ kN}$$

$$SF = \frac{P_{ULT}}{P_s}$$

$$SF = \frac{(133.445 \text{ kN})}{(19.89 \text{ kN})}$$

$$SF = 6.709$$

The Bearing Swivels are, therefore, acceptable under seismic loading for two reasons:

- The seismic load (P_s) is less than the Working Load Limit (P_w)

- The Ultimate Load is high enough to provide an acceptable safety factor when the member is loaded under seismic conditions.

4.3 CORNER CLAMP W/ LIFTING LUG (AAA99-109705)

Bearing Stress

$$\sigma_b = \frac{P_s}{2t \cdot d}$$

$$\sigma_b = \frac{19890 \text{ N}}{2(0.01905 \text{ m}) \cdot (0.0195 \text{ m})}$$

$$\sigma_b = 26.772 \text{ MPa}$$

$$\sigma_y = 240 \text{ MPa}$$

$$SF = \frac{\sigma_y}{\sigma_b}$$

$$SF = 8.96$$

4.4 LOCATOR PIN (AAA99-109705-01)

Shearing

$$\ell = 0.0375 \text{ m}$$

$$d = 0.01 \text{ m}$$

$$A = \ell \cdot d$$

$$\tau = \frac{V}{A}$$

$$\tau = \frac{P_s}{2\ell \cdot d}$$

$$\tau = \frac{19890 \text{ N}}{2(0.0375 \text{ m}) \cdot (0.01 \text{ m})}$$

$$\tau = 26.520 \text{ MPa}$$

Von Mises:

$$\sigma_{vm} = \sqrt{3}\tau$$

$$\sigma_{vm} = 45.934 \text{ MPa}$$

$$\sigma_y = 248.2 \text{ MPa}$$

$$SF = \frac{\sigma_y}{\sigma_{vm}}$$

$$SF = 5.403$$

4.5 CORNER CLAMP (AAA99-109704)

Bearing Stress Due to Locator Pin

$$d = \frac{D}{3} = 0.00333 \text{ m}$$

$$t = .04 \text{ m}$$

$$\sigma_B = \frac{P_s}{2t \cdot d}$$

$$\sigma_B = \frac{19890 \text{ N}}{2(0.04 \text{ m}) \cdot (0.00333 \text{ m})}$$

$$\sigma_B = 74.662 \text{ MPa}$$

$$\sigma_Y = 240 \text{ MPa}$$

$$SF = \frac{\sigma_Y}{\sigma_B}$$

$$SF = 3.214$$

4.6 LOAD BEARING HEX SCREW (N5305-10215)

$$F_{bolts} = F_{bolt_s} \cdot f_{AS}$$

$$F_{bolt_s} = (4.980 \text{ kN})(2.21)$$

$$F_{bolt_s} = 11.006 \text{ kN}$$

$$F_{S_s} = (2.862 \text{ kN})(2.21)$$

$$F_{S_s} = 6.325 \text{ kN}$$

$$A_B = 1.5708 \cdot 10^{-4} \text{ m}^2$$

$$\sigma_{vm} = \left(\frac{1}{A_B} \right) \sqrt{F^2 + 3F_s^2}$$

$$\sigma_{vm} = \left(\frac{1}{1.5708 \cdot 10^{-4}} \right) \sqrt{(11.006 \text{ kN})^2 + (6.325 \text{ kN})^2}$$

$$\sigma_{vm} = 98.860 \text{ MPa}$$

$$\sigma_Y = 240 \text{ MPa}$$

$$SF = \frac{\sigma_Y}{\sigma_{vm}}$$

$$SF = 2.428$$

4.7 PIVOT PIN (AAA97-100278)

$$F_{pivot} = F_{pivot} \cdot f_{AS}$$

$$\begin{aligned}F_{\text{piv}_s} &= (3.221 \text{ kN})(2.21) \\F_{\text{piv}_s} &= 7.118 \text{ kN} \\\tau &= \frac{F_{\text{piv}_s}}{t \cdot h} \\&= \frac{7.118 \text{ kN}}{(0.038 \text{ m})(0.005 \text{ m})} \\&= 37.465 \text{ MPa}\end{aligned}$$

Von Mises:

$$\begin{aligned}\sigma_{vm} &= \sqrt{3}\tau \\&= 64.892 \text{ MPa}\end{aligned}$$

$$\begin{aligned}\sigma_y &= 248.2 \text{ MPa} \\SF &= \frac{\sigma_y}{\sigma_{vm}} \\&= 3.825\end{aligned}$$